Farming 4.0

Handbook for improvement of the ICT skills for VET in agriculture

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Erasmus +

Contents

1 INTRODUCTION OF THE PROJECT

Rising demand for bigger yields and higher environmental protection has put pressure on the agricultural sector to “produce more with less”. Smart farming or “farming 4.0.” could hold the key. In Europe, Precision Agriculture (PA) and the integration of digital technology are set to become the most influential trends in the sector, as a growing number of farmers start to adopt digital technologies to run their businesses. According to the machinery industry in Europe, 70 to 80% of new farm equipment sold now has some form of PA component technology inside. There are 4,500 manufacturers, producing 450 different machine types with an annual turnover of € 26 billion. The sector also employs 135,000 people. However, the uptake of Precision Farming in Europe is still very low. For instance, only 35% of new fertilizer spreaders are sold with a precision weighing instrument included, essential for adjusting quantity and direction of spread. Precision Farming can potentially help farmers produce higher yields, less crop damage and fewer inputs such as water, fuel and fertilizer. The European Joint Research Center estimates that PA can make a huge $CO2$ saving contribution in European agriculture until 2030.

The main project foundations is to develop and implement a specifically designed curriculum for ICTs for agricultural purposes and the knowledge and skills for delivering this curriculum through VET. The goal is to achieve more successful adoption of specifically developed ICTs for agriculture, that will contribute to the development of the agricultural sector and the rural areas. Considering the important role of the young farming population and the advisors in the agricultural extension for the development of the agriculture, we have put special attention on creating a curriculum for the following target groups: high school students, farmers, advisers and teachers. Additional aspect that is considered in defining the target group, is involving individuals with special needs. Also, we believe that ICTs increase the opportunities, for the people with special needs, as well as their employability within the agricultural sector.

The main idea behind ITShape project was to develop ICT curricula for the vocational education aligned with the T-Shaped model (is term used in job recruitment to describe the abilities of persons in the workforce). The vertical bar on the T represents the depth of related skills and expertise in ICTs, whereas the horizontal bar is representing the non-job-specific skills, the so-called “transversal skills”, like communication, achievement orientation, etc.

In this project, the consortium intends to utilize the results of ITShape project, in order to adopt the learning outcomes, the approach and T-Shaped model for agricultural VET students, with special focus on the increasing demands for advanced digital skills in the labour market related to the Farming 4.0 phenomena.

The curriculum is developed by applying e-Competence Framework (e-CF) model, including four dimensions as follows:

- Dimension 1: Five competence areas (PLAN, BUILD, OPERATE, ENABLE and MANAGE);
- Dimension 2: A set of reference e-Competence for each area;

- Dimension 3: Proficiency level of e-Competences related to EQF levels 3 to 8; and
- Dimension 4. Sample of knowledge and skills related to e-Competences in dimension 2.

2 TYPES OF EDUCATION

Lifelong learning is a never-ending process, the main purpose of which is to keep up with the developments in time. In recent years, it has been influenced the most by the constant development of digital and information technologies, which have entered all areas of human activity.

According to the material of the **Strategy for Educational Policy of the Czech Republic until 2020**, the following three types of educational opportunities are recognised – **formal education, non-formal education and informal learning**[1].

Formal education takes place primarily in schools/colleges/universities and leads to achieving different levels of education (basic education (elementary, primary education), secondary education, secondary education with an apprenticeship certificate, secondary education with a school-leaving examination (A-Levels), higher vocational education at an Academy of Performing Arts, higher vocational education at a College of Further and Higher Education, university education). Pre-primary education, basic arts education and language education also have characteristics typical of formal education in the Czech Republic. Their roles, goals, contents, organisational forms and methods of evaluation are clearly defined.

Non-formal education focuses on the development of knowledge, skills and competencies. It takes place in facilities of employers, private educational/training institutions and schools (e.g. education that is part of leisure activities focused on a variety of topics), non-governmental, non-profit organisations, libraries and other institutions. Some leisure activities organised for children, young people and adults, such as various workshops, training and retraining courses and lectures are also included as part of non-formal education activities. The implementation of non-formal education requires involvement of an expert lecturer, teacher or trainer. However, non-formal education does not lead to the formal acquisition of a certified level of education unless the learning outcomes are recognised by the relevant body or institution.

Informal learning can be understood as a process of spontaneous acquisition of knowledge, skills and competencies based on everyday experience and activities at work, in the family and in free time. It also includes self-education, where the learner does not have the opportunity to verify the learning outcomes. Informal learning, unlike formal and non-formal education, is not organised and coordinated at an institutional level, it is usually non-systematic in nature and lacks the shaping influence of a teacher.

There are different **forms of education: full-time**, **distance** and **combined form**. When combining full-time and distance forms, we talk about so-called **blended-learning**.

Lifelong learning has been one of the most important topics in social discussion for a long time. It is becoming apparent that the need for education does not end with the completion of formal

[1] http://www.vzdelavani2020.cz/images_obsah/dokumenty/strategy_web_en.pdf

education and training in primary, secondary or tertiary education, but that this period is rather a preparation for the lifelong learning and education process. We are moving towards a society that provides all parts of the population with an opportunity during their lifetime to acquire and get recognised qualifications that can be used in the labour market, and to improve the key competences needed for employment, civic and personal life.

As early as 2006, the following key competences were identified at the European Parliament and the Council Meeting on Key Competences for Lifelong Learning, which describe the basic knowledge, skills and attitudes related to each of these competences[2]:

- Communication in the mother tongue, ie the ability to express and interpret concepts, thoughts, feelings, facts and opinions in both oral and written form and to respond in an appropriate and creative way in all situations of social and cultural life.
- Communication in foreign languages, ie the ability to communicate (same as in case of the mother tongue above) including the need to understand a different culture.
- Mathematical competence and basic competences in science and technology, ie the ability to develop and apply mathematical thinking to solve a range of problems in various everyday situations with an emphasis on process, activity and also knowledge.
- The ability to work with digital technologies, ie the ability to use Information Society Technology (IST) in a confident and critical way, it presupposes basic skills in the area of information and communication technologies.
- Ability to learn, ie the ability to carry out this activity and organise learning individually or in a group according to one's own learning needs, with an awareness of methods and possibilities.
- Social and civic competences include personal, interpersonal and intercultural competences and cover all forms of behaviour that equip individuals to participate in an effective and constructive way in social and working life. They are closely linked to personal and social well-being. It is essential to understand the codes of conduct and manners generally accepted in different societies. Civic competences, in particular knowledge of social and political concepts and structures (democracy, justice, equality, citizenship and civil rights), prepare individuals for an active and democratic participation in civic life.
- A sense of initiative and entrepreneurship is the ability to put ideas into practice. It presupposes creativity, the ability to innovate and take risks, and to plan and manage projects in order to achieve certain goals/objectives. The individuals are aware of the context of their work and are able to seize the opportunities that arise. It is the foundation for more specific skills and knowledge needed by those involved in social or business activities. This should include awareness of ethical values and promotion of good governance.

2 https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006H0962:EN:HTML

- Cultural awareness and expression meaning appreciation of the importance of the creative expression of ideas, experiences and emotions in various forms (including music, performing arts, literature and visual arts).

Lifelong learning values and appreciates the potential for further development of the personality, and the ability to learn new things in accordance with the dynamically evolving needs of society. It also strengthens the social cohesion of society, increases human adaptability, balances life opportunities, reduces the marginalisation of disadvantaged groups, and thus contributes to social stability.

There is no precise and uniform definition for lifelong learning (sometimes referred to as lifelong education), also due to the fact that lifelong learning is interpreted in different ways in different countries.

There is a definition by the European Commission that lifelong learning is "*all learning activity undertaken throughout life, with the aim of improving knowledge, skills and competencies within a personal, civic, social and/or employment-related perspective*".[3] From this it is clear that an individual goes through the process of lifelong learning from birth.

The so-called **intergenerational learning** also plays an important role in lifelong learning. This form of education (learning) is seen as "*a process that aims to bring people together in purposeful, mutually beneficial activities which promote greater understanding and respect between generations and can contribute to building more cohesive communities*". Probably the most common place where intergenerational learning takes place is the environment of the family, especially in case of families where several generations live together. The most natural type of such learning is when parents teach something their children. It can be said that for a child, parents are not only a role model, but also the most important teachers, and they do not lose this role even when the child starts going to school. The importance of grandparents, who have a lot of life and professional experience that they can pass onto younger generations, is also significant. However, it is not the rule that in intergenerational learning, the older generation has automatically the teaching role. Especially with the constantly growing importance and influence of ICT in everyday life, the most common "teachers" for the older generation are their children or grandchildren.

Due to the ever-increasing amount of media content and its impact on society, **media literacy** is playing an increasingly important role. Nowadays, this is one of the most important competencies. Only media literate individuals are able to process information correctly in the flood of misinformation/disinformation and fake news.

[3] https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Lifelong_learning

3 TRENDS IN DISTANCE EDUCATION

If we would like to find out where education is going and how it changes over time, we need to look at pedagogical and technological trends.

The following trends can be listed as **pedagogical trends**:

- Wider range of learning strategies – Teacher requires not only memorisation, but also shows a way for a good orientation in a large amount of information, and how to make use of the information well.
- Achieving learning objectives/outcomes effectively – Using multimedia elements enable achieving a wider range of learning objectives compared to using just printed materials.

Technological trends can be divided into three major areas:

- Full electronisation − The use of e-learning, LMS and the Internet is becoming more and more common in education.
- Interactive teaching elements − Simulations of real events/processes are used in teaching instead of just static visual information (motivation, clarity); the percentage for using games in education is also increasing.
- Virtual reality as a learning environment − The illusion of the real and fictional world is another trend that is helping to make teaching more efficient and interactive.

New technologies affect all areas of life. It is essential to learn to work with the technologies effectively in order to work well in a society and the labour market. For that it is necessary not only to keep constantly acquiring the latest knowledge, which disseminates very quickly due to the interconnectedness of the world, but also to learn to use the technologies effectively and creatively.

However, the implementation of technologies depends on the context of their use. The purpose of their application must be clear. The effectiveness depends on the people and the way they use the technologies, their abilities, motivation, skills and the context in which they will work with technologies. Thus, technologies in education can be beneficial only if they support the needs of the students and lecturers.

Significant changes were brought to the web with the development of technologies. In 2004, users gained the ability to use the online environment to produce their own content. This stage is called **Web 2.0**. The development of synchronous technologies such as video conferencing or chat rooms has brought human feelings and real-life experiences to education.

Other technologies that have greatly influenced online education include **mobile phones**. They provide students with more flexible, independent and individualised learning opportunities. Education has become independent of time and place.

Learning Management Systems (LMS) have been introduced for the management of teaching materials, monitoring of pupils and teachers, or individualisation of teaching processes. At the beginning, LMS could only present the content of the course in a basic form. As technology develops new interactive features get added. New LMS generation offers flexible configurations and a more personalised and formative evaluation structure.

There are many predictions about EdTech (Educational technology) trends, however almost all of them agree on two technologies – **Artificial Intelligence (AI) and Machine Learning** and **Virtual Reality (VR) and Augmented Reality (AR)**.

In the context of education, **AI** is referred to as a tool for personalised learning that can fill in the required gaps in the education process, and therefore enable schools and teachers to focus more on other essential matters.

It has been talked about personalised learning according to the specific needs of individual students for a long time, however AI brings new possibilities to this issue.

In regular classes of thirty students, there is not much room for personalised teaching. However, AI technology could make this possible. Based on the information about the student, AI would create an individual learning plan for each student. In addition, from the processed data AI can easily reveal patterns and ways in which the student understands and processes the learning material, and can work with this further. AI can also help to check tasks and tests. Some tests can be checked and evaluated by technology/machines today already, such as multiple-choice tests. However, in the future technology/machines could also evaluate written answers. AI can not only work with them very fast, but it could also offer recommendations to fill in gaps in learning.

Augmented reality (AR) and virtual reality (VR) are already creating a comfortable space for teaching. AR and VR enable creating realistic scenarios for students. The digital environment accelerates acquiring a higher level of understanding and memorisation compared to the traditional classroom teaching. Virtual worlds help students gain valuable hands-on experience that they would not otherwise have access to. The cost of technology, which is getting lower and lower, allows institutions to invest in effective and active educational tools. It was predicted that by 2023 there will be almost 3.4 billion AR-compatible smartphones.

Cloud technologies are also increasingly used for teaching. Their main strengths include the active involvement of each student, creating an environment for shared interactive collaboration, expanding the educational space outside the school premises, saving time on lessons preparation, and enabling different approaches to selected groups and individuals.

If we focus on the motivation of an individual, the following five basic characteristics are known to be the characteristics of an optimal educational environment:

- The student can move freely in the environment.
- The student receives immediate feedback on its performance.
- The student can progress at his/her own pace.
- The student is not limited by the environment when discovering/learning.

- The student is encouraged to discover the context.

Such an environment can be found in computer games, which often contain highly motivating factors that affect the player's behaviour and its ability to learn while playing. There is the concept of **gamification**, which represents the principle of using game elements in a non-game environment.

There are a number of tools (e.g. Minecraft, Khan Academy, Duolingo, MathBoard, etc.) that allow the teacher to partially transfer the learning process to a form of a game, in which students are motivated to complete tasks, such as gaining experience and skills for their avatar, working together or communicating with teachers during and outside the teaching process. Students can share their achievements and evaluate each other.

Distance learning is a widely used form of education in **lifelong learning**. It is a multimedia form of guided study that provides new educational opportunities and supportive educational services for usually self-studying adult participants, where the main responsibility for the course and education results lies with students who are physically separated from teachers (consultants).

Distance learning can take place in the form of **online** or **offline** teaching. The term **online** teaching generally refers to a type of distance learning that usually takes place via the Internet and is supported by a variety of digital technologies and software tools. We distinguish between **synchronous** and **asynchronous online** teaching.

In **synchronous** teaching, the teacher is connected with the children/pupils/students usually via a communication platform in real (same) time. The group is working on the same/similar task at the same time in the same virtual location.

In **asynchronous** teaching, children/pupils/students work on the tasks assigned to them at a time selected by them and at their own pace. They do not meet together in the online space. For this type of work various platforms, portals, applications, etc. can be used, both for the training itself and for assigning tasks and providing feedback.

3.1 WHERE TO GET INSPIRED?

Estonia, which ranks among the top in education in Europe, provides its materials at: https://education-nation.99math.com/

Figure 1: Screenshot of the Top Remote Learning Solutions in Estonia.

For example **3DL** is an app that can be downloaded by teachers and students from the Mac store, Windows Store, Google Play and Appstore. It provides over 1000+ content elements - 3D Models, videos and animations. Students and teachers can use it for learning and teaching. Users can make their own videos, answer quizzes and puzzles. www.3dl.no

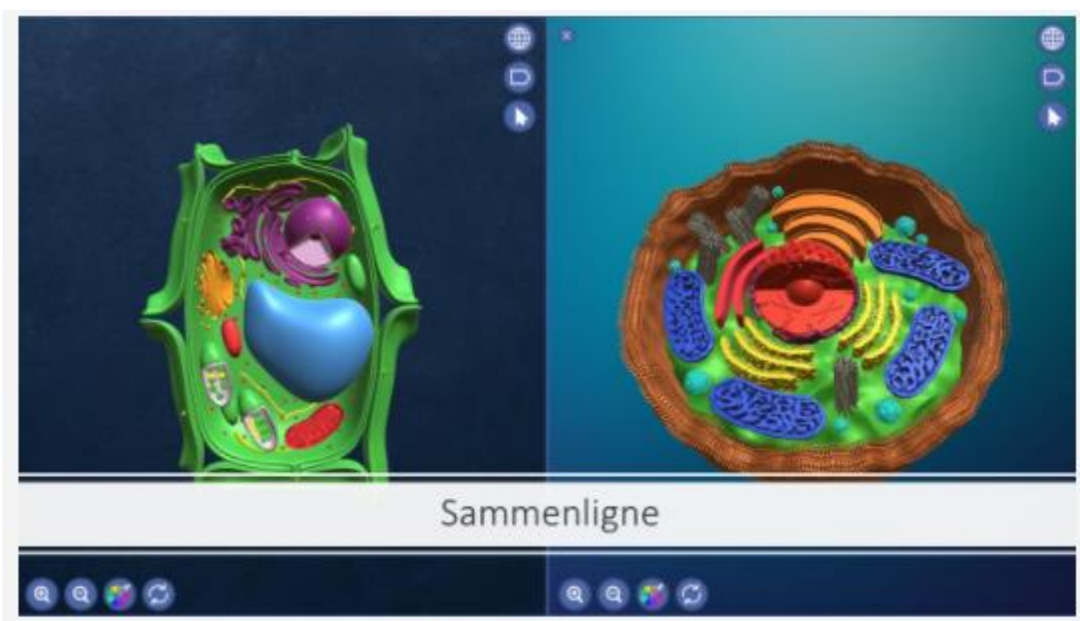
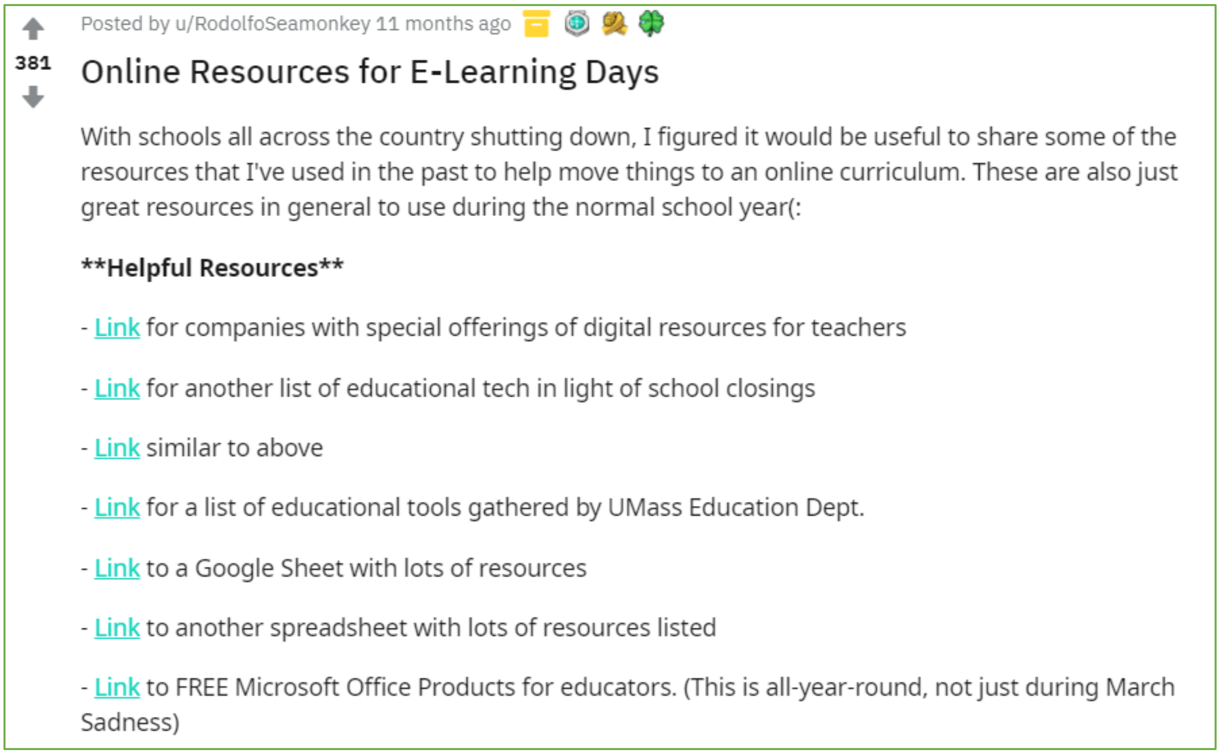


Figure 2: Screenshot of the 3DL.

The **Reddit** social network has a wide range of resources for online education – lists of organisations and projects

https://www.reddit.com/r/Teachers/comments/fhgkyj/online_resources_for_elearning_days



Posted by u/RodolfoSeamonkey 11 months ago

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Online Resources for E-Learning Days

With schools all across the country shutting down, I figured it would be useful to share some of the resources that I've used in the past to help move things to an online curriculum. These are also just great resources in general to use during the normal school year(:

Helpful Resources

- Link for companies with special offerings of digital resources for teachers

- Link for another list of educational tech in light of school closings

- Link similar to above

- Link for a list of educational tools gathered by UMass Education Dept.

- Link to a Google Sheet with lots of resources

- Link to another spreadsheet with lots of resources listed

- Link to FREE Microsoft Office Products for educators. (This is all-year-round, not just during March Sadness)

Figure 3: Screenshot of the Reddit.

3.2 LEGISLATION AND DOCUMENTS

White Paper on Education and Training. Teaching and Learning towards the Learning Society. [online] Accessible at: www.europa.eu/documents/comm/white_papers/pdf/com95_590_en.pdf

4 ONLINE EDUCATION POSSIBILITIES

Online education is a flexible instructional delivery system that encompasses any kind of learning that takes place via the Internet. Online learning gives educators an opportunity to reach students who may not be able to enroll in a traditional classroom course and supports students who need to work on their own schedule and at their own pace.

Online education has become a viable and exciting method for instructional delivery in the global business society that runs on a 24/7 schedule (24 hours a day/7 days a week) because it provides students with great flexibility.

Learning Management Systems

A learning management system (LMS) is a software application for the administration, documentation, tracking, reporting, automation and delivery of educational courses, training programs, or learning and development programs.

Most modern LMSs are web-based. There are a variety of integration strategies for embedding content into LMSs, including AICC, xAPI (also called 'Tin Can'), SCORM (Sharable Content Object Reference Model) and LTI (Learning Tools Interoperability). LMSs were originally designed to be locally hosted on-premise, where the organization purchases a license to a version of the software, and installs it on their own servers and network. Many LMSs are now offered as SaaS (software as a service), with hosting provided by the vendors.

LMS Moodle

Moodle is a free and open-source learning management system distributed under the GNU General Public License. Moodle is used for blended learning, distance education, flipped classroom and other e-learning projects in schools, universities, workplaces and other sectors.

Google Classroom

Google Classroom is a free web service developed by Google for schools that aims to simplify creating, distributing, and grading assignments. The primary purpose of Google Classroom is to streamline the process of sharing files between teachers and students.

Google Meet

Google Meet is a video-communication service developed by Google.

MS Teams

Microsoft Teams is a proprietary business communication platform developed by Microsoft, as part of the Microsoft 365 family of products. Teams primarily competes with the similar service Slack, offering workspace chat and videoconferencing, file storage, and application integration.

Zoom

Zoom Video Communications, Inc. (or simply Zoom) is an American communications technology

5 FARMING 4.0

Agriculture 4.0 also called Farming 4.0 or digital agriculture, in the narrower sense, precision agriculture means the intertwining of

- information and communication technologies (ICT),
- decision support based on the processing of bigdata,
- automation and robotization.

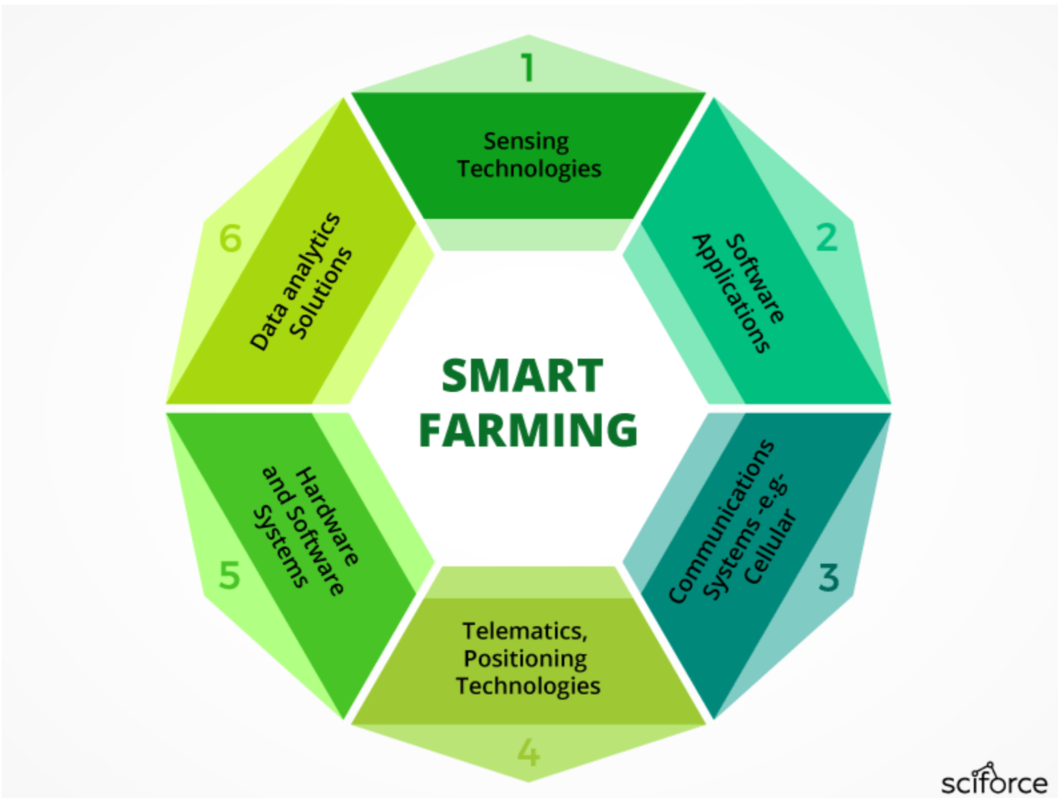

Figure 4: Technologies involved in smart farming, Beecham Research Source: Medium.com

We can also say that this is a reform of technology and management that will lead to a change in the business models of production, plant management and product lines. But how did we get there?

Precision farming is a combination of technical, IT, information technology and crop technology applications that make crop production and agricultural machine management more efficient. At the same time, it supports environmental and sustainability expectations (Gebbers and Adamchuk, 2010).

Precision Agriculture is a system that can apply the right agricultural operation at the right place and time. Agri-informatics tools, systems, services are generally related to the concept of precision farming, which by its present definition is a complex farm management system that adapts production processes through the means of observation, measurement and intervention, according to time and geographical variations.

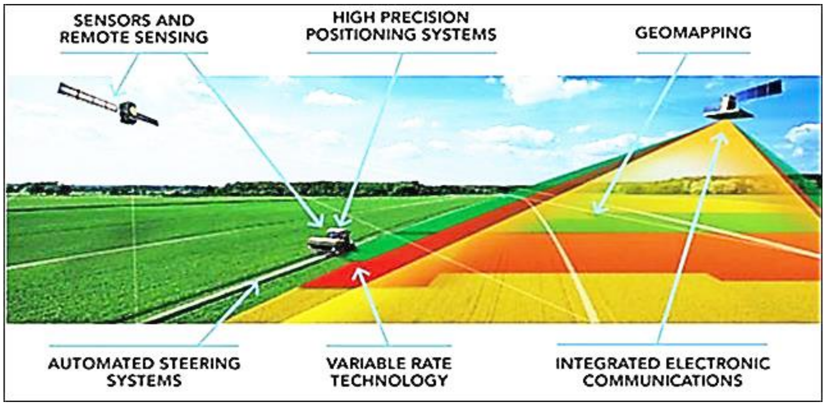

Figure 5: Precision Agriculture concept.
Source: ResearchGate

6 DATA SOURCES

6.1 SAMPLING

In agriculture, it is essential for the farmer or consultant to think and plan ahead, which requires sufficient quality and quantity of data. Recently, farmers and consultancy companies have come to realize that not all farm fields are the same, but due to the large size of the fields, there may be significant differences within it.

The practical implementation of precision farming requires that we measure and understand the spatial and temporal variability of soils and plants within the field.

Sampling can be:

- Soil sampling
- Live-stock sampling
- Production sampling

Soil sampling

In soil science, soil is defined as 'an independent body in nature with a unique morphology from the surface down to the parent material as expressed by the soil profile'. The main objective of soil sampling in the context of precision agriculture is to understand the nutritional levels in the soil over separate and distinct areas (zones) within a field subject to cultivation, and hence observation.

The basis for mapping differences within a field is well-defined, well-planned soil sampling, which is suitable for mapping homogeneous patches (zones) within the field.

During precision soil sampling, the fields are divided into smaller areas or zones, soil samples are taken within each zone, then the required nutrient doses for each zone are designed and the nutrient supply is delivered in a targeted and differential manner.

By performing analyses on soil samples, agricultural experts and farmers can begin to understand the relationship between soil fertility levels and other properties of the field that can be predicted and measured. Factors that influence soil nutrient levels, and hence the determination of the soil sampling approach to be employed, include:

- soil type
- topography
- cropping history
- manure applications
- land levelling for irrigation
- fertilizer management practices.

Live-stock samling

The main purpose of livestock sampling is to

- monitoring animal health, early detection of diseases and infections at the level of individual animals
- monitoring the activity and behaviour of each animal
- collection of data to support decision making at farm or organization level

There is a wealth of information we can collect about animals, whether it is one-off, regular or ad hoc.

The collected information is processed by computer software, the data analyzed serve as a basis for decision support and provide the opportunity for feedback to plan and execute the necessary quick interventions.

Production sampling

It is necessary to provide a representative sample to a laboratory for analysis in order to determine whether an agricultural product complies with regulations such as:

- Maximum Residue Limits (MRLs) for chemical residues
- Maximum Levels (MLs) for metal residues
- Determining whether soils contain organochlorine insecticide residues such as dieldrin or DDT, which are a concern to many agricultural interests.

There are a set of general rules for sampling fruit, vegetables and grains. The following procedures are based on sampling methods as recommended by the Codex Alimentarius Commission and the Food and Agriculture Organization. Sampling should be performed separately in the following situations:

- with different fruits, vegetables or grains
- with different cultivars or varieties
- in areas of crop which have had different chemical treatments, or which have been sprayed on different days
- with produce sourced from different growers for repacking or processing.

6.2 REMOTE SENSING

For the proper operation of intelligent machine groups, it is important to have real-time knowledge of soil, plant, environmental and especially operational characteristics. This is provided by various sensor systems. In systems based on sensory measurement, the following types of sensor can be found:

- soil sensors: electrical conductivity, soil salinity, soil moisture, soil temperature, etc.,
- plant sensors: stock characteristics, crop moisture, nutrient supply, etc.,
- environmental sensors: relative humidity, air temperature, precipitation, wind speed and direction, leaf humidity, solar radiation, etc.,
- function monitoring sensors (machine).

Source: Dr. Jóri J. István: A jövő mezőgazdasága

Based on the measurement technology, several sensors are distinguished:

- Electromagnetic: Used to measure soil, salinity, organic matter and moisture.
- Optical: Optical sensors have reflectivity to characterize the soil. Used to predict the moisture content of clay, organic matter and soil
- Air: measures the air permeability of the soil
- Acoustic: Used to determine soil texture
- Electrochemical: Measures soil nutrient and pH

Remote sensing can be:

- Soil sensing technologies
- Crop sensing technologies
- Sensors in Live-stock
- Sensors for Agricultural Machines
- Environmental or meteorology sensors

In soil sensing technologies are used:

- Spectroradiometer – is hyperspectral (high spectral resolution, up to hundreds of bands) sensor. This type of sensor collects and processes information in the electromagnetic spectrum, which makes it possible to identify and measure soil characteristics.
- Frequency-domain reflectometry FDR and capacitance sensors - are developed for measuring soil moisture content. FDR and capacitance probes measure the soil dielectric constant using two or more plates or rods which are embedded into the soil.
- Penetrometer – is a tool used to test the compaction level and tilt of your soil. Penetrometers measure the resistance of the soil, giving an indication of how compacted your soils are as an indication of the soil quality.
- Shear strength sensor – is soil resistance to deformation by applied external shear forces, for example, during soil cutting process with different tillage tools. Sensors can measure the shear resistance of the soil in different depths as they pass through the field.

Crop sensing technologies are:

- Nutrition management, plant health and plant protection
    - Sensors for nutrient management – are a wide range of sensors, which are available to produce vegetational indexes of plants that measure plant development and photosynthetic activity. Based on their principle of operation, there are two types, passive and active sensors.
    - Sensors to detect plant stress - The reduction of qualitative and quantitative losses of crop production and the achievement of higher yields largely depend on the early detection of various plant diseases and pests. Optical techniques such as RGB colour, multi - and hyperspectral imaging, heat maps, or chlorophyll fluorescence sensors can detect plant diseases at an early stage.
- Sensors for plant protection

- Laser rangefinder sensors and laser scanners – are widely used for industrial purposes and for remote sensing. In agriculture information about crop parameters like volume, height, and density can support the optimization of production processes.
- Time-of-Flight 3D camera – is also use a built-in light source, capable of simultaneously processing depth and intensity information on each pixel. Provides 3D images with an accuracy of 1 cm and a high frame rate.
- Hyperspectral imaging – is the detection of light reflected by the crop with the use of specialized sensors. Almost every farming issue (weeds, diseases, nutrient deficiency, etc.) changes a physiology of the plant, and therefore affects its reflective properties.
- Weed control – can be done with real-time technology where weeds are detected and treated at the same time. Cameras mounted on the tractor take pictures across the field, then the computer evaluates the data and the controlled sprayer handles the marked spots.
- Precision (sensor driven) cultivation – enables inter-row cultivation. An autopilot ensures accurate 2 cm return accuracy for seeding (seeding) and row parallelism. The autopilot saves time, since the operator does not have to count the rows, and on the other hand, the optical sensor mounted on the cultivator ensures that the cultivator's blades do not cut the rows.
- Pest management – scout crops for pest pressures, surveillance and management of pest insect populations is a key issue for successful plant protection. Farmers conduct periodic surveys of insect traps in their area, although this activity is labour and time consuming.

- Sensors in live-stock
  - Electronic identification – Individual identification of animals is a prerequisite for implementing PFL. This is the "backbone" of all PFL systems.
  - Foot mounted accelerometers – these sensors are used in a number of areas, such as farm estrus detection, health monitoring, activity, steps, lying and standing behaviour.
- Sensors for agricultural machines – there are many different sensing technologies in precision agriculture that provide data that help farmers monitor soil or plants to optimize processes and adapt to changing environmental factors. These sensors can be:
  - positioning sensors that use signals from GPS satellites to determine latitude, longitude and altitude
  - optical sensors that use the properties of light to measure soil properties
  - electrochemical sensors that carry key information such as pH or soil nutrient supply
  - mechanical sensors for measuring the physical properties of soil
  - soil moisture sensors
  - air flow sensors that measure the air permeability of the soil
  - weather station sensors.

- Environmental and meteorology sensors
  - Meteorology and climate based controls – include there three groups:
    - Signal-based sensors use publicly available meteorological data (temperature, sunlight, humidity) and calculate the ET value of the grass surface at a given location. The ET data is then transmitted wirelessly to the irrigation controller.
    - Traditional ET sensors use a pre-programmed water use curve based on water use in different regions. The curve can be adjusted as a function of temperature and sunlight.
    - Local meteorological sensors use weather data collected at a given location for continuous ET measurement and water volume calculation
  - Soil moisture based sensors – instead of using weather data, soil moisture sensors are located below the soil in the root zones of the plant to determine water demand. Soil moisture sensors provide estimates of soil water content.
  - Other sensors
    - Wind sensors
    - *Rain and frost sensors*

6.3 OPEN SOURCE

Satellite data

The European Union has an own Earth observation program called Copernicus program, which currently has six satellite families known as Sentinel satellites. Sentinel-2 satellites provide useful information and satellite imagery for agriculture. The satellites produce accurate, reliable, high-quality, diverse information and data types on a daily basis, which can be useful for identifying plant types and for monitoring the condition and growth of vegetation.

Sentinel mission

The EU and ESA are currently developing seven missions under the Sentinel program. These include radar and super-spectral imaging to monitor land, ocean and atmosphere. Each Sentinel mission includes two satellites that perform and re-examine the coverage requirements for each mission, providing reliable data sets.

Sentinels 1 and 2 has a specific agricultural purpose and provides a range of additional, up-to-date information on the whole of Europe every 3-4 days.

Orthophoto

The orthophoto looks like a traditional photo, but is free from any geometric distortion, has a uniform aspect ratio, allowing accurate measurements. Like most maps, orthophotos are the orthogonal projections of the Earth's surface. It combines the beneficial features of photos and maps therefore often called as a "photo map".

Weather data and forecast

Almost every National Hydro Meteorological Institute provides, not only an overview of current weather conditions and short-term forecasts. As well as data from national organizations, there are a number of applications and tools for the future. These applications make it very easy to obtain basic weather information. Some of the most widely used applications and tools are YR, Windy, OpenWeatherMap, etc.

7 DIGITAL FARM MANAGEMENT SYSTEMS AND EQUIPMENT

7.1 MACHINES AND TECHNOLOGY

Numerous new and advanced information and communication technologies can be applied to farming 4.0 systems and software solutions, which are central to research and development, and in many cases are driving forces for innovation.

Intelligent machines

Intelligent machine refers to a tractor-implement group or a stand-alone power machine that can identify its geodetic work point, determine the need for cultivation, measure, evaluate, and change the machine setup and work quality.

System conditions:

- tractor / power machine with on-board computer, DGPS and ISOBUS;
- digital maps (crop, nutrient, weed, cultivation);
- implement with ISOBUS system (sensors and tools);
- site-specific application solutions.

Positioning System (DGPS)

Main features of DGPS / RTK positioning system:

- Differential correction can greatly improve the accuracy of GPS data.
- Essentially, at least two locations are being collected at the same time. On the one hand, it has a known position on a stable ground station (the so-called reference station) and on the other hand it has an unknown position on other GPS receivers.
- Reference station data can be used to compensate for mobile GPS receiver errors.
- Accuracy: ± 2 cm.

Digital maps

In addition to positioning, various digital maps are essential for the proper operation of intelligent machine groups, which provide setup / cultivation requirements for the on-board computer.

Sensors

A further precondition for the proper operation of intelligent machine groups is the real-time knowledge of soil, plant, environment and, above all, operational features provided by various sensor systems.

Tractor-implement management (ISOBUS ISO 11783)

The basis of precision crop production is the intelligent machine groups. Methods and tools for locating the system and specifying operational requirements are described above. However, these are necessary but not sufficient conditions for precise operation. The tractor-implement assembly can only operate accurately if they can communicate with each other. This is achieved by the ISOBUS (ISO 11783) system.

Tractors – Soil tillage

Farmers most often use GPS, remote sensing and geographic information system (GIS) to obtain the maximum possible information on soil condition and quality and to apply the required amount of fertilizer, water and nutrients based on the data. In order for farmers to be able to manage land properly while respecting all the principles, some engineers and manufacturers are also trying to help, by producing machines for inter-row mechanical cultivation of wide-row crops and machines for pre-sowing preparation. These are designed for soil-protective technologies that are closely linked to precision farming.

Autonomous tractors, that is to say, driverless tractors are of great interest to agricultural machinery manufacturers and farmers themselves. These machines are now being developed based on existing tractors, but they are equipped with electronic components for automatic tool recognition and its width.

Seeders, Sowing Control Systems

Precision seeders

They let seeds through one after another. They allow seed savings of the order of 25 to 30%. They are used primarily for sows of sugar beets, sunflower and maize. They are somewhat harder to use for rape due to a small working speed of about 6 km/h and a limited spread. It is possible to use them when a smaller plant density is required in a row ranging from 10 to 18 seeds to a normal metre, and it is necessary to avoid the risk of lengthing the stem and lie-down.

Sowing Control System

This system ensures a balanced distance between the falling seeds. The density of sowing varies according to the different crop types. The spread in small grains ranges from 150 to 400 seeds per m^2.

Seed-spray-irrigation-fertilizer machines

With a machine that can read such maps, the measure is applied in practice: the GPS-guided machine tracks the map and continuously adjusts the fertilizer or herbicide dose based on it. The potential benefits of using a precise application of nitrogen fertilizers can be higher yields per ha, nitrogen fertilizer savings, better crop harvesting conditions, higher quality of harvested commodities, less nitrogen leaching to groundwater, etc.

Harvesters

Harvesting in a precision farming system uses combine harvesters equipped with a GPS yield meter, which produces data that can be used to generate yield maps. These yield maps show

how much grain was harvested in specific parts of the site and are then used to produce variable fertilization application maps.

Autopilots

Autopilots or automatic controls are technical devices that enable tractors, harvesters and other machines used in precision farming to refine the routing of individual rides. Driving with autopilots is always more accurate than driving manually without any assistance.

Variable Rate Technology

- Site-specific Nutrient Management (SSNM) – aims to optimize the supply of soil nutrients over time and space to match the requirements of crops, soil or that location. The amount of seed, nutrient or chemical to be applied within the field is changed based on a prescription map.
- Variable Rate Technology (VRT) – the intelligent machine groups of precision agriculture systems, with the abilities described above, can perform variable rate operations includes soil cultivation, nutrient supply, spraying, sowing, irrigation.

IoT

The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

Yield mapping and monitoring

Sensors are installed on combines and harvesters for continuous measurement of grain volume. With the help of these data they are able to calculate the yield. Several types of sensors have been developed for yield measurement that operate on different principles, e.g. impact plate system, metering cell system, balance cell system, infrared sensor system, gamma ray system.

7.2 SW AND SYSTEMS

Geographical Information System (GIS)

GIS is a specialized information system for analyzing geographical data. GIS is considered as a system of hardware, software and various methods that help to collect, manage, process, analyze, model, and render spatial data for complex design and management tasks.

Enterprise IS (ERP, DSS, planning, business, etc.)

Enterprise information systems provide a technology platform that enables organizations to integrate and coordinate their business processes on a robust foundation. Their most widely used and well-known manifestations are the Enterprise resource planning (ERP) systems.

ERP

Enterprise resource planning (ERP) is business process management software that allows an organization to use a system of integrated applications to manage the business and automate many back-office functions related to technology, services and human resources.

DSS

DSS are used for planning and analyzing activities, and for aiding decision-making. A Decision Support System (DSS) is defined as an information system application that assists the mangers in decision making. They generally include: a database, a model base, and a user interface.

Farm Management Information Systems (FMIS)

The Farm Management Information System (FMIS) has evolved from a simple farm record to a sophisticated and complex system. They are designed to support production management, reduce production costs, meet agricultural standards, and ensure high product quality and safety.

Farm record keeping and reporting

Farm record keeping usually means the administration of main production units - inputs, land parcels, livestock heads, etc. -of the farm and the main activities - tillage operations, cultivation practices, application of materials etc.- performed during the actual farming period.

Agricultural production management

Within the category of agricultural information systems, various farm management software has emerged as a more complex solution. Farm Management Software are used to optimize and manage farm operations and production activities. The software helps in automating farm activities such as record management, data storage, monitoring and analysing farming activities, as well as streamlining production and work schedules.

7.3 SERVICES

The needs of farmers are changing as a result of new pressures and emerging opportunities. As the farm sector evolves, service providers must also evolve.

There are many services on the market to support the farm sector to be productive, competitive and sustainable. This major group includes:

- soil preparation services,
- crop services,
- veterinary services,
- other animal services,
- farm labor and management services,
- landscape and horticultural services.

In today's agriculture, information about the field is becoming more and more important, therefore, many service providers appeared on the market offering different data collecting methods. Soil sampling methods, aerial imagery, sensor-based technologies are very popular to collect as much valuable information as possible.

8 DATA INTEGRATION

The agriculture sector has its own data complexities and challenges, some of which may be specific to the sector.

For example, an individual farm may collect data on a wide range of fronts - plant production results, livestock production, farm food production, etc. There is therefore an essential need for data integration.

There are two key considerations for data integration:

- combining results from all fields of interest
- timing – obtaining results in acceptable timeframes.

Both of these should be targets for data integration, or ‘data warehousing’ - technologies that are used to aggregate structured data from one or more sources so that it can be compared and analysed for greater business intelligence. This is at the heart of digital farm management systems.

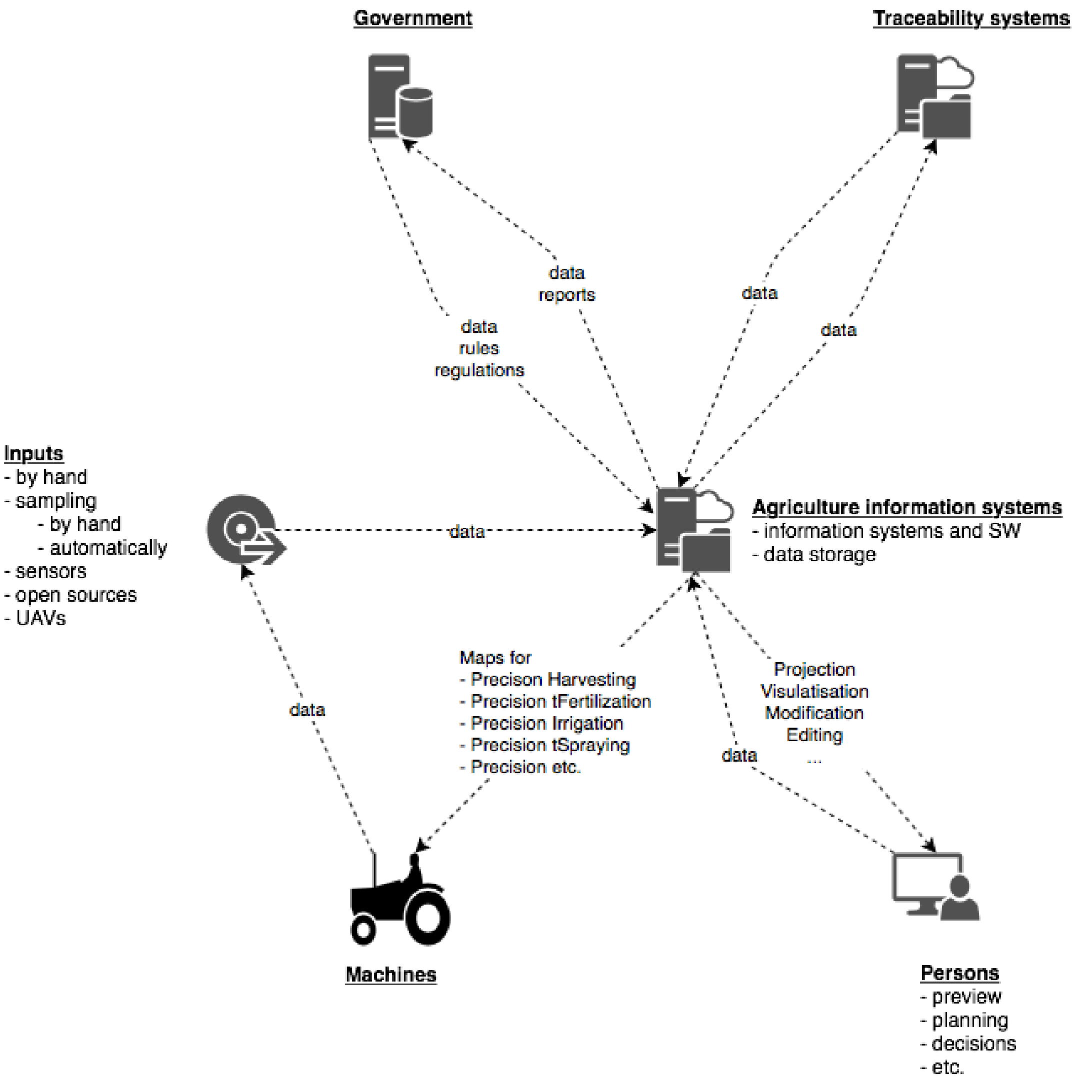

Figure 6: Data Integration concept.

9 TRACEABILITY SYSTEMS

Traceability is the ability to track and follow the movement of products throughout the food chain, i.e. all stages and operations involved in the production, processing, distribution, storage and handling of a food and its ingredients - from production to consumption.

Food safety and quality management systems have been developed to establish and maintain a traceability system, enabling the identification of products to batches of raw materials, processing and delivery records. Traceability is of such importance that it has become a regulatory requirement.

The ISO standard sets out the principles and specifies the basic requirements for the design and implementation of a traceability system in the agro-food and feeds industry.

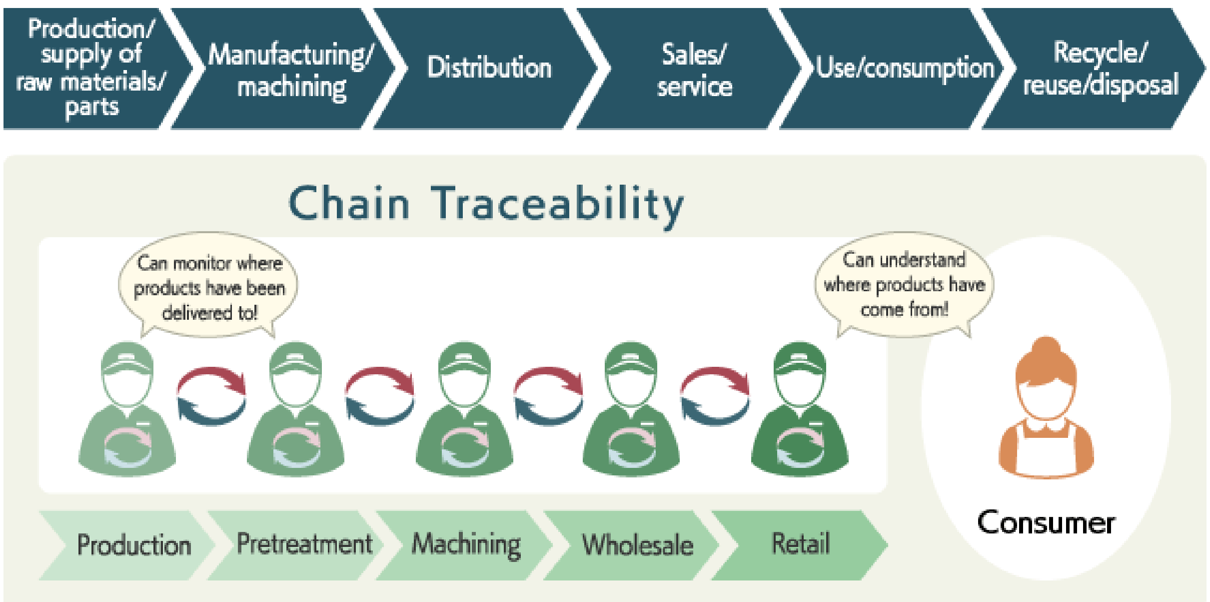

Figure 7: Traceability systems process
Source: Keyence.com

10 FINAL SUMMARY AND RECOMMENDATIONS

Precision agriculture is a long-used term for modern approaches to farming and livestock production, it respects the natural variability of the production environment and tries to respond to it. However, it turns out that technical progress in the field of navigation, sensors, electronics, information technology, transmission, storage, processing and interpretation of data exceeds the possibilities of individuals or individual companies to effectively use this information and thus the potential of the whole idea of precision agriculture is not fully utilized.

Precision agriculture is a typical interdisciplinary field that must effectively combine a range of cutting-edge knowledge from the technical, biological, and economic sciences.

Therefore, this idea, which is more than 20 years old, is not yet fully implemented in practice, at least not in the extent that was expected at the beginning of the development of precision agriculture. Many of the problems in the relationship between the technical and biological aspects of precision agriculture were underestimated and proved to be far deeper during development than originally thought. Therefore, in practice, only some elements of this originally complex system are commonly used (e.g., machine navigation, yield maps, fertilization according to nutrient supply). The overall potential of precision agriculture is thus only partially exploited.

From foreign experience regarding precision agriculture, it is evident that in countries where there is an interconnected system of education and state support for precision agriculture, these technologies are used to a far greater extent (Australia, Germany, USA). The question, of course, may be whether there was first technological development to which the education system responded, or whether it was education that caused technological development in the first place. In any case, this system has evolved in developed countries over the last 20 years and is proving to be very effective. Therefore, if the state is interested in supporting modern forms of agricultural production, the "Comprehensive educational system of precision agriculture" should also be an integral part of the proposed measures. The generally accepted premise is that investment in education is highly efficient, therefore use of this tool should yield significant benefits.

The main goal of the precision agriculture education system is the sustainable development of agricultural efficiency and competitiveness. This approach should include:

- The entry of new skilled people into agriculture
- Effective sharing of knowledge among the agricultural public
- Development of modern forms of agricultural production
- Dynamic implementation of research outputs into practice

Such a system is based on foreign "best practices". The system includes all levels of education, all relevant subjects, and is based on modern educational trends. Basic study aids and elements of the proposed system are:

10.1 CATALOGUE OF PRECISION AGRICULTURE TECHNOLOGIES

Precision agriculture is an all-encompassing term with several sub-disciplines, the content of which is a set of technologies and procedures used. However, the current way of presentation and education lacks any kind of systematics or ontology characterizing precision agriculture with all concepts, connections, and processes. In most cases, it is based on explaining the issue by a specialist in a certain sub-area, or representatives of companies offering their products. A large part of the professional public then lacks the necessary contexts.

The aim of the Catalog of Precision Agriculture Technologies is to provide basic study support for all proposed levels of education, to create a logically structured and comprehensible characteristics of processes representing precision agriculture with all used technologies and links between them and clearly describe their benefits.

The intended way of developing the catalogue and keeping it up to date is based on current principles of knowledge sharing. A professionally created basic framework should be made available to the professional community and further development will be based on wiki principles.

10.2 MULTIMEDIA COURSES IN PRECISION AGRICULTURE

The aim of the Multimedia Courses is to facilitate the online availability of study materials to support the teaching of precision agriculture, especially in secondary schools (even for schools not primarily focused on agriculture) and also form the starting material for the establishment of the Virtual PA Academy for the agricultural public.

The content covers complex issues of precision agriculture, individual specialties, processes, technologies, and interrelationships.

The courses are based on the principles of eLearning, serve to support contact teaching in secondary schools and at the same time enable self-study. The form is adapted for optimal use by the target group - high school students. It contains motivational videos, it is possible to study on mobile devices, it includes instructions for solutions (curriculum - exposition part), tasks for independent solution (fixation part), recommended sources of information and verification of knowledge (self-tests). There is also a possibility to add webinars on current topics.

The course is available via the internet and is very easy to use for teachers as well as for use by high school students and the agricultural community.

10.3 RESEARCH OUTPUTS

Universities and research institutes are constantly generating a large amount of new knowledge. Its transfer into practice is also a constantly discussed matter. More than anywhere else, there is an important ongoing contact between the agricultural community and representatives of science and research, so that the requirements of agricultural practice placed on research are correctly defined and the results obtained are in turn adequately used.

11 OTHER SOURCES

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